

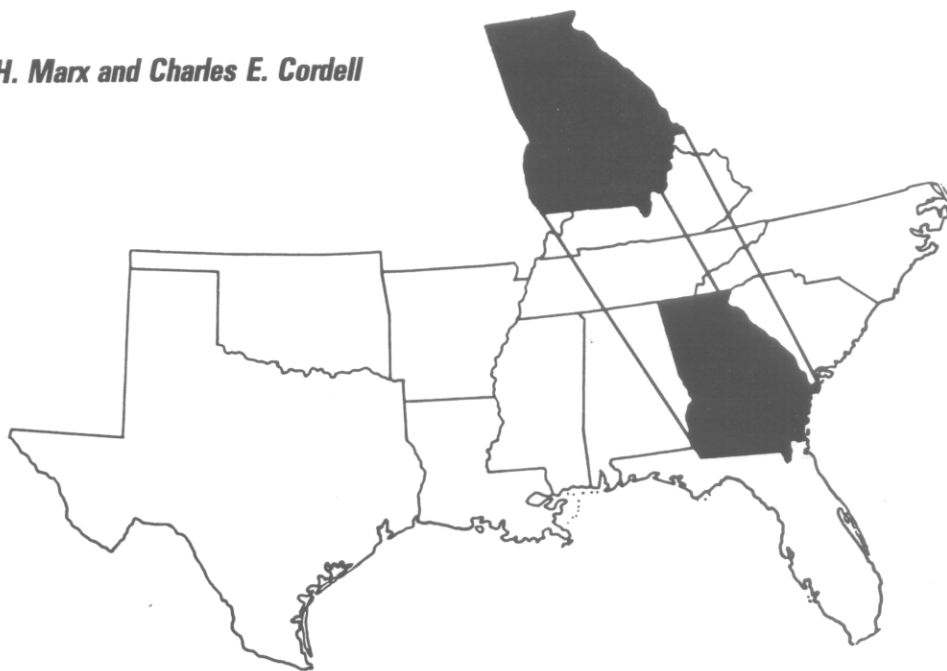
Research
REPORT

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***PISOLITHUS* Ectomycorrhizae** FILE COPY
Improve 4 - Year Performance Of
Loblolly And Slash Pines In South Georgia

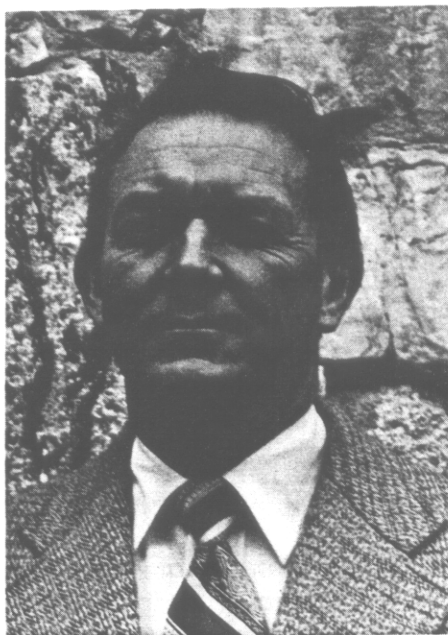
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ABSTRACT

Growth of loblolly and slash pines was significantly improved after 4 years on good-quality sites (site index 80) by *Pisolithus tinctorius* ectomycorrhizae formed in a nursery prior to outplanting. Trees with only naturally occurring ectomycorrhizae from the nursery grew slower especially during years of low rainfall. In the driest years, *Pisolithus* ectomycorrhizae resulted in per-acre volume and weight increases for loblolly pine of 43 and 37 percent, respectively, and increases for slash pine of 22 percent for both parameters.

PISOLITHUS ECTOMYCORRHIZAE IMPROVE 4-YEAR PERFORMANCE
OF LOBLOLLY AND SLASH PINES IN SOUTH GEORGIA

INTRODUCTION

Fine roots of all tree species, including southern pines, are symbiotically colonized by specific mushroom and puffball-producing fungi, and the results are special root structures called ectomycorrhizae. Ectomycorrhizae occur naturally on certain tree species in forests throughout the world and are essential to the survival and growth of the trees and the fungi. Ectomycorrhizae aid the tree in water and nutrient absorption and deter certain diseases of fine roots. The fungi obtain all their essential organic nutrient requirements, especially carbohydrates, from the tree. There are hundreds of species of ectomycorrhizal fungi in southern pine forests. Some of the fungi are more beneficial to the tree on certain sites than are other fungi.

In the last decade, considerable research has been done on one particular puffball-producing fungus, Pisolithus tinctorius (Pers.) Coker & Couch (Pt), to determine its effect on tree survival and growth on a variety of sites. On sites with adverse soil conditions such as coal spoils (Marx and Artman 1979, Berry 1982, Walker and others 1982), borrow pits (Ruehle 1980, Goodwin 1982), and kaolin spoils (Marx 1977, Otrosina 1977), and on severely eroded sites such as the Copper Basin in Tennessee (Berry and Marx 1978), pine seedlings with abundant Pisolithus ectomycorrhizae formed in the nursery survive and grow better after outplanting than seedlings with ectomycorrhizae formed in the nursery by naturally occurring fungi, such as Thelephora terrestris (Ehrh.) Fr. On better soils, such as good-quality reforestation sites in the South, pine

seedlings with *Pt* ectomycorrhizae may (Marx and others 1977, Marx 1979, Mexal 1980, Ruehle and others 1981, Kais and others 1981, Vermillion 1982, Hatchell and Marx 1987) or may not (Powers and Rowan 1983, Leach and Gresham 1983) survive and grow better than nursery-run seedlings. There are two possible reasons for lack of improved growth in these reports. First, past work has shown that a minimum threshold proportion of the ectomycorrhizae on a seedling must be formed by *Pt*. If not, growth rates will be comparable to those of nursery-run seedlings having large quantities of naturally occurring ectomycorrhizae. Second, since *Pt* is beneficial mainly on a stressed sites, benefits are small when little stress occurs. Recently, Marx and others (in press) reported that improvements in field performance of loblolly pine through age 8 on a good site (site index 90) in Early County, Georgia, were positively correlated with high initial amounts of *Pt* ectomycorrhizae on seedling roots at planting and with severe to moderate soil water deficits during the different growing seasons. Abundant *Pt* ectomycorrhizae significantly improved tree growth during drought years on this good site, but all trees, regardless of initial ectomycorrhizal status, grew at similar rates when soil moisture was adequate.

The objectives of the study described here were (1) to determine the effects of abundant *Pt* ectomycorrhizae on survival and growth of loblolly and slash pine after 4 years on good-quality reforestation sites in Brantley County, Georgia, and (2) to determine whether growth differences due to *Pt* ectomycorrhizae were related to rainfall amounts during the growing season.

MATERIALS AND METHODS

Seedling Production

Loblolly (Pinus taeda L.) and slash (P. elliottii Engelm. var. elliottii) pine seedlings from South Georgia improved seed orchards were grown at the Walker State Nursery, Reidsville, Georgia, in 1982. Nursery cultural practices included spring soil fumigation, machine inoculation of nursery soil with research vegetative inoculum of Pt, seeding and fertilization according to procedures described by Marx and Hatchell (1986). Triadimefon (Bayleton) spray was used to control fusiform rust caused by Cronartium quercuum (Berk.) Miyabe ex Shirai f. sp. fusiforme Burdsall and Snow. This systemic fungicide caused erratic suppression of ectomycorrhizal development through September (Marx and others 1986).

On December 16, 1982, seedling beds were undercut to 8 inches and seedlings were hand-lifted. They were graded to eliminate culls, to select similar sized seedlings, and to visually assess ectomycorrhizal development. From the Pt inoculated nursery plots, 800 seedlings of each pine species were obtained, bundled in groups of 100 seedlings, packed in kraft paper seedling bags with moist peat moss, and stored at 36 °F until planting. Pt index of these seedlings ranged from 64 to 81. The same numbers of seedlings of each pine species (same seed source) were hand-lifted from noninoculated plots, graded, bundled, and stored in identical fashion. Ectomycorrhizae formed by naturally occurring Thelephora terrestris occurred on an average of 48 percent of feeder roots on these naturally inoculated (NI) control seedlings. Ungraded nursery-run seedlings were lifted, packed, and stored for planting in border rows.

Outplanting Site

The study site is in Brantley County on the Big Creek Seed Orchard, Dixon Memorial State Forest, Waycross, Georgia. The loblolly pine planting site was occupied by a natural stand of longleaf (P. palustris Mill.) which was clearcut in 1978 and cleared. Agricultural crops, mainly soybeans and wheat, were grown yearly from 1979 to 1981. The soil is a Blanton sand. Analysis by A&L Laboratories, Memphis, Tennessee, of several randomly located soil samples collected at planting time from throughout the site showed the following results: 0.040 percent total N, 12 lb/ac available P, 25 lb/ac K, 420 lb/ac Ca, 40 lb/ac Mg and soil pH was 5.5. Estimated loblolly pine site index is 80 feet at age 50. The site for the slash pine study was also clearcut in 1978 of the natural longleaf pine, but was not planted in crops. It was sheared, root-raked, burned, and disked in early 1982. The soil is Blanton sand and Klej loamy sand. Soil analysis at planting time was 0.044 percent total N, 4 lb/ac P, 21 lb/ac K, 300 lb/ac Ca, 37 lb/ac Mg and soil pH was 5.3. Estimated slash pine site index is 80 feet at age 50.

Experimental Design and Seedling Measurements

Seedlings of both species were planted on December 27-29, 1982, with a Whitfield planter on a 9- x 7-ft spacing in 8 adjacent blocks. Each block contained a row of 100 Pt seedlings and a row of 100 NI (control) seedlings. Each of these rows was bordered by a row of nursery-run seedlings. In all, 33 rows of 100 seedlings of loblolly and equal numbers of slash pine were planted.

In January 1983 after several rains had settled the seedlings, initial height and root-collar diameter of each test seedling were measured. Statistical analyses of these data indicated no significant differences between treatments

at planting. Similar measurements were made after the 1983, 1984, 1985, and 1986 growing seasons. In 1986, diameter at breast height (DBH) also were measured. Individual-tree and per-acre volumes and individual-tree and per-acre green weights at age 4 were derived from heights and DBH measurements with equations of Clark and others (1985) and Phillips and McNab (1982). Data were subjected to a simple two-way analysis of variance. Trees were also separated into three size classes of height, DBH, volume, and green weight to determine frequency distribution as affected by the initial ectomycorrhizal treatment.

Rainfall data for each growing season (February through November) were obtained¹ from a weather station approximately 3 miles from the study site. Differences between treatments in yearly increments of height and root-collar diameters of both tree species were related to deviations in monthly rainfall from the 4-year average.

RESULTS

Seedling survival of both pine species was excellent and was not affected by treatment. After 4 years, root systems of trees of both species had closed both in and between rows and the canopies of most trees had closed in the rows.

Loblolly pine seedlings with *Pt* ectomycorrhizae were significantly taller and had significantly larger DBH measurements than control seedlings after 4 years (Table 1). These growth differences resulted in average tree volume and tree weight increases of 50 and 36 percent, respectively. On a per acre basis, the volume and weight increases were 43 and 37 percent, respectively. The

¹ Furnished by James T. Paul, Project Leader, Forestry Weather Data Systems, Southern Forest Fire Laboratory, Southeastern Forest Experiment Station, Route 1, Dry Branch, GA.

loblolly pines were separated into three size classes for height, DBH, volume, and fresh weights. There were always more Pt trees in the largest size classes and more control trees in the smallest size classes (Figure 1).

Slash pine seedlings with Pt ectomycorrhizae were also significantly taller and had larger average DBH than control seedlings after 4 years (Table 1). These differences resulted in estimated tree volume and tree weight differences of 25 and 21 percent, respectively. Per-acre volume and weight increases due to Pt ectomycorrhizae were each 22 percent. The slash pines also were separated into three size classes for height, DBH, volume, and fresh weight. Again, there were more Pt than control trees in the largest size classes and more control than Pt trees in the smallest size classes (Figure 2).

Figure 3 shows the relationships between monthly rainfall deviation from the 4-year average and yearly increments of height and root-collar diameter. Although total growing season rainfall was 3 inches above average in 1983 and 1984 these growing seasons had 5 and 7 months, respectively, of below average rainfall. Differences in yearly increments of height and root-collar diameter between Pt and control trees of both tree species were nearly the same for each of these growing seasons. The 1985 growing season also had 5 months of below average rainfall, but total rainfall was 4.8 inches above average. Differences in height and root-collar diameter growth between the two treatments were considerably less for both pine species in this year than in the two previous years. The 1986 growing season was very dry, having 8 months below average rainfall. Total rainfall for 1986 was 6.4 inches below average. For both pine species differences in height growth between treatments were minimal. However, growth in root-collar diameter was far greater for Pt trees than for control

trees during this dry growing season. Pt trees had over 25 percent more increase in root-collar diameter than control trees during the 1986 growing season.

DISCUSSION

These results clearly show that growth of loblolly and slash pines can be significantly improved on good quality forest sites during years of low rainfall by having abundant Pt ectomycorrhizae on seedling roots at planting. The test sites (site index 80) are typical of many good quality forest sites in the coastal plain of Georgia. Growth differences due to Pt ectomycorrhizae were reflected in size class distribution of trees. For both species, a much larger proportion of the Pt than control trees are in the largest size classes. Since root closure has already occurred on these sites, the larger trees should maintain growth rate superiority over smaller trees in the future.

During the year of least rainfall (1986), in both loblolly and slash pines, the advantage of Pt ectomycorrhizae was reflected primarily in diameter rather than in height growth. This result suggests an increased allocation of carbon and other assimilates to the root system during dry years resulting in a greater diameter growth rate. During wetter years, a more balanced carbon and assimilate allocation occurs (Landsberg 1986).

The relationship between soil water deficit and growth differences due to Pt ectomycorrhizae can only be implied from the rainfall deficiency data presented here. However, earlier studies (Marx and others, in press, Walker and others 1982) have shown positive growth response during periods of soil water deficits. These data suggest that trees with only naturally occurring ectomycorrhizae (i.e., nursery-run seedlings) have slowed growth during periods of soil water

deficits. Trees with *Pt ectomycorrhizae* grew at faster rates through dry periods. Results are significant growth differences between trees of the different ectomycorrhizal treatments during years of low rainfall. Over the 4 years of this study, these differences in growth rates resulted in a 50-percent larger tree volume for loblolly pine and a 25-percent larger tree volume for slash pine.

The results suggest that root systems with abundant *Pt ectomycorrhizae* may be more capable of either extracting or utilizing available water and, thus, essential nutrients from soil during periods of low water availability than are trees with only naturally occurring ectomycorrhizae. Periods when this advantage is apparent occur fairly often, even on good quality sites. This improved capacity is likely mediated by the extensive fungal hyphal strands formed by *Pisolithus* in the root-soil zone. Absorption and utilization of soil water by hyphal strands of ectomycorrhizal fungi and its translocation to tree hosts have been demonstrated (Duddridge and others 1980, Boyd and others 1986).

These results have significant and immediate practical implications. Most soils in southern commercial forests have 2 to 3 years of severe to moderate water deficits during any 5 year period (Marx and others, in press). Even during years of adequate total rainfall, severe to moderate water deficits are apparently routine occurrences during 1 or more months of the growing season. Even trees on a good-quality forest site have slowed growth rates during these drought months or years. Results of this and other research indicate that *Pt ectomycorrhizae* can alleviate a significant amount of this growth loss during plantation establishment, regardless of site quality. The techniques, equipment, and commercial inoculum sources necessary to tailor large quantities of southern pine seedlings with *Pt ectomycorrhizae* in bare-root and container nurseries are now available.

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Table 1. Survival and growth of loblolly and slash pines with Pisolithus or naturally occurring ectomycorrhizae after 4 years in Brantley County, Georgia^x

Treatment	Survival	Height (ft)	DBH (in)	Tree volume ^y (ft ³)	Per-acre volume ^y (ft ³)	Tree weight ^z (lb)	Per-acre weight ^z (lb) x 10 ²
Loblolly pine							
<u>Pisolithus</u>	98a	11.7a	2.0a	0.12a	73a	12.8a	78a
Natural	97a	10.8b	1.7b	0.08b	51b	9.4b	57b
Slash pine							
<u>Pisolithus</u>	97a	10.8a	1.9a	0.10a	61a	11.1a	67a
Natural	97a	10.1b	1.7b	0.08b	50b	9.2b	55b

^x For a given tree species and measurement, means sharing a common letter do not differ significantly at $P = 0.05$.

^y Volume equation from Clark and others (1985).

^z Weight equation from Phillips and McNab (1982).

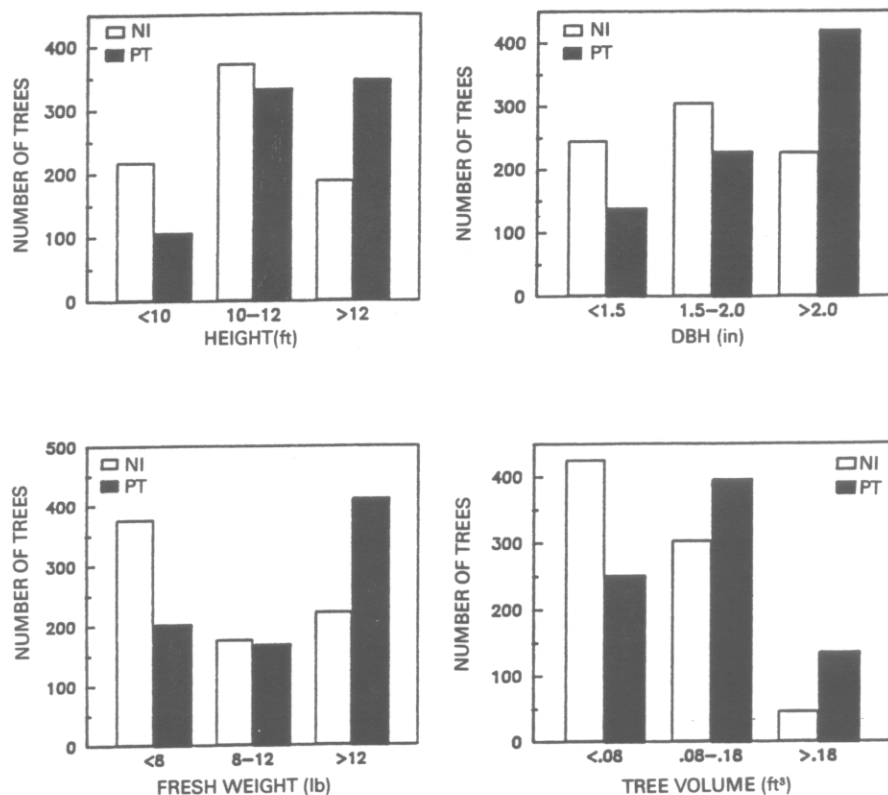


Figure 1. -- Distribution of loblolly pine by size classes for height, diameter breast high (DBH), tree fresh weight, and tree volume as affected by *Pisolithus* (Pt) or natural (NI) ectomycorrhizae after 4 years.

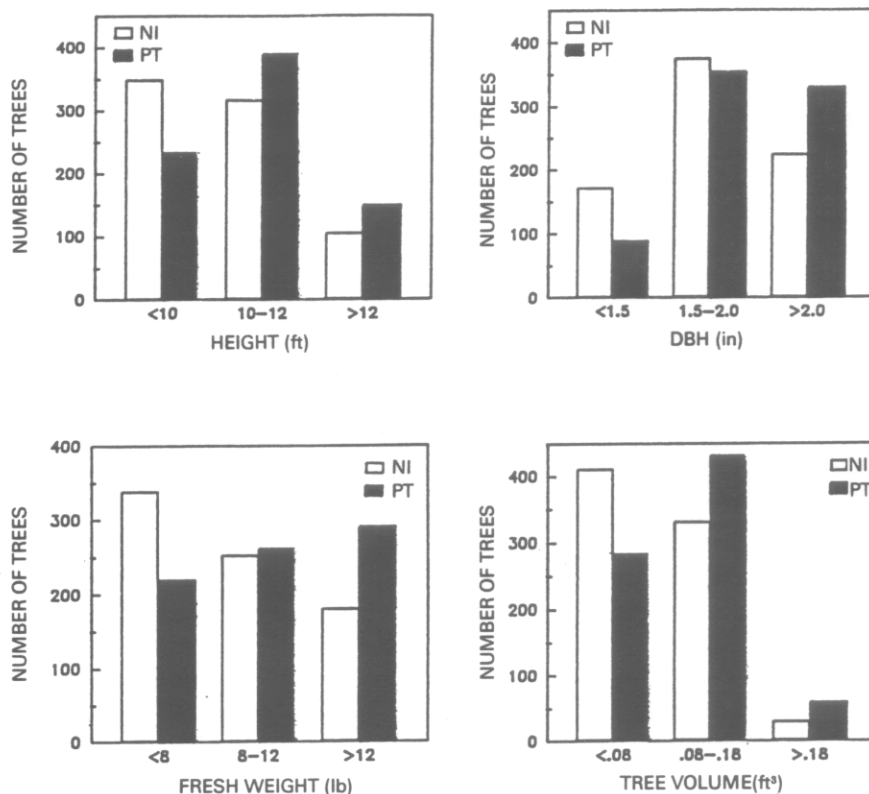


Figure 2. -- Distribution of slash pine by size classes for height, diameter breast high (DBH), tree fresh weight, and tree volume as affected by *Pisolithus* (Pt) or natural (NI) ectomycorrhizae after 4 years.

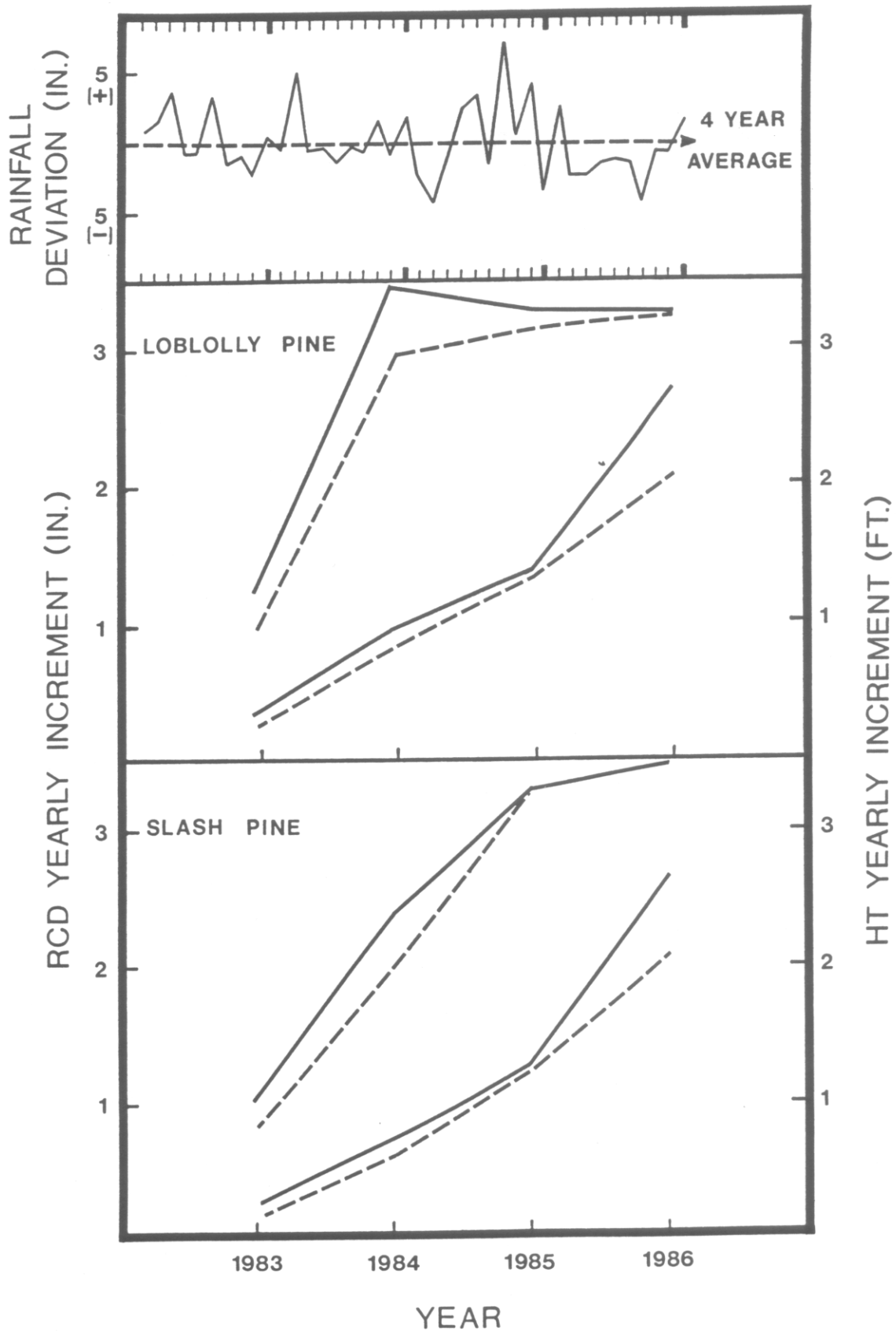


Figure 3. -- Monthly deviation of rainfall from the 4 year monthly average during each of the four 10 month (Feb. - Nov.) growing seasons and annual increments of height (X) and root collar diameters () of loblolly and slash pines with *Pisolithus* (solid lines) or naturally occurring (dashed lines) ectomycorrhizae on good quality sites in South Georgia.



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